THE DISTRIBUTION AND FACTORS INFLUENCING THE AMOUNT OF SEBUM ON THE SKIN OF THE FOREHEAD[1]

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Emanuel (1) claims that there is a limited height or amount of sebum on the skin surface, and he has suggested that this height is regulated by the sebaceous layer resisting the functional output of the gland. Our experiments (2) also show that a level or amount is reached on the skin surface since we were able to collect little more once weekly than at each daily collection. Our previous work, however, does not provide any confirmatory evidence that the sebum on the skin surface is a factor in limiting further exudation. The amount of surface sebum may be regulated by volatilization or resorption of the sebum when on the skin surface at a rate which equalizes the rate of the output of the gland.

In our experiments there was also some variation in the amount of sebum which could be collected once weekly or daily from the forehead. If surface sebum is a factor in determining the amount which can be collected, the variation could be due to some change in the resistance of the surface sebum which would allow more exudation or excretion. The variation, on the other hand, could be due to a greater output by the gland which in some way would overcome the resistance afforded by the sebum.

It is not known whether the sebum forms a film or layer on the skin surface or if the sebum is confined to conical masses around each gland orifice. Emanuel (1)apparently considers that the sebum forms a film on the skin surface since he frequently refers to the sebaceous layer. It seems important that the distribution of the sebum on the skin surface be investigated since the distribution may supply information if and how the sebum on the surface is a factor in regulating further exudation.

This investigation is, therefore, concerned with these problems: 1) does the sebum exist as a film or layer on the skin surface of the forehead or is it confined to conical masses around the gland orifices; 2) is the amount on the skin surface regulated by volatilization or resorption of the sebum; 3) what will cause a variation in the amount which can be collected daily?

METHODS AND RESULTS

1. *The Distribution of the Sebum on the Skin Surface.* Observation of the skin of the forehead under the stereoscopic microscope showed mounds of sebum and cellular debris at the orifices of the glands. The sebum was fluid in consistency and while there appeared to be some sebum distributed over the skin between the orifices of the glands, particularly in the sulci, this point was hard to ascertain with certainty.

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In order to more carefully study the distribution on the skin surface, the sebum was removed from small areas of skin with cotton and ether. At intervals following the removal of the sebum, the areas were exposed to osmic acid vapors by holding the mouth of a small vial containing cotton and a few drops of osmic acid against the skin for 30 seconds.

Figures 1 and 2 show areas with a 12-hour accumulation of fat which was blackened with osmic acid vapors. The black dots are due to the accumulation at the orifices of the glands and the adherence of the sebum to the hairs. The

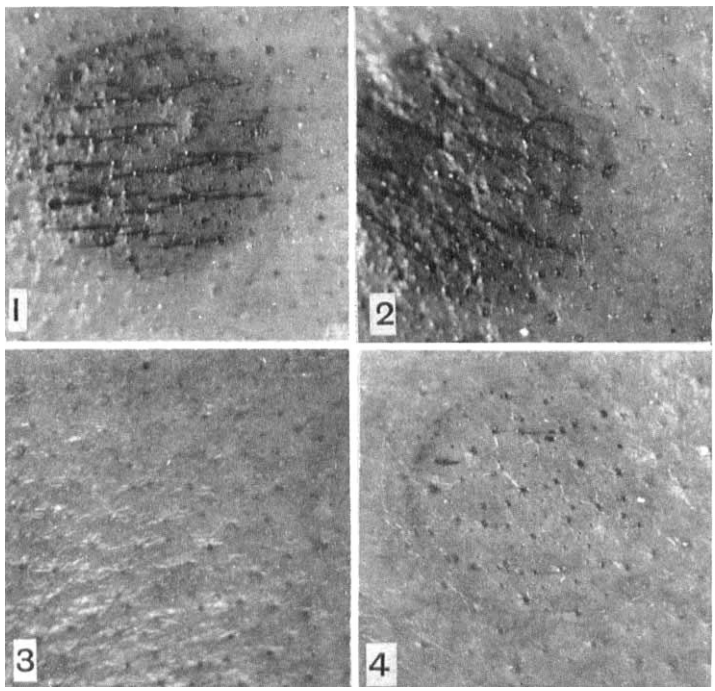

FIG. 1 (upper left) and FIG. 2 (upper right) show the sebum which accumulated in an interval of 12 hours at the orifices of the glands and in the sulci of the skin. It has been blackened with osmic acid vapors.

FIG. 3 (lower left) shows skin which was cleaned with ether and immediately exposed to osmic acid vapors. No sebum appears to be present.

FIG. 4 (lower right) shows the sebum which accumulated in an interval of 15 minutes. Sebum is present in many of the orifices of the glands and has spread in the sulci in a few instances.

streaks radiating from the dots represent the spreading of the fat in the sulci. In some instances, the fat has run together between the orifices of the glands. Outside of the blackened area may be seen numerous clear spherical masses of fat at the orifices of the glands. Figure 3 shows skin that was cleaned with ether and immediately exposed to the osmic acid vapors. There is no blackening since little fat was left on the surface of the skin. Figure 4 shows the accumulation after an interval of 15 minutes. The orifices of many of the glands show the presence of fat. There has been a spreading in the sulci in a few instances. The

fat as it exudes from the orifice of the gland is thus not entirely confined to elevations around the orifices of the glands, but spreads in the sulci.

2. *Is the Amount on the Skin Surface Regulated by Volatilization or Resorption of the Sebum?* The method of collection was described extensively in a previous paper. Briefly, it consisted of collecting the sebum with an Emanuel cup (3) in which was placed ether-alcohol for 90 seconds. The amount of fat was then determined by Bloor's nephelometric method.

TABLE 1

Showing amount of fat in mg./sq. cm. collected under various conditions from forehead

CASE NO.	CLEANED WITH ETHER, LEFT UNCOVERED 12 HOURS	NO CLEANSING, COVERED 12 HOURS	CLEANED WITH ETHER, COVERED 12 HOURS	CLEANED WITH ETHER, COVERED WITH $CaCl_2$ CUPS 12 HOURS
1	0.145		0.304	
2	0.092		0.296	
3	0.121		0.223	
4	0.153		0.275	
5	0.153		0.333	
6	0.168		0.208	
7	0.110		0.151	
8	0.110		0.147	
9	0.113		0.153	
10	0.130			0.211
11	0.090			0.197
12	0.158			0.275
13	0.096			0.168
14	0.092	0.208		
15	0.147	0.179		
16	0.133	0.232		
17	0.156	0.290		
18	0.130	0.226		
19	0.087	0.179		
20	0.084	0.191		
Average.....	0.123	0.215	0.232	0.213
Average.....	0.123		0.220	

When the sebum[2] was removed hourly for 8 hours, an hourly average of 0.032 mg./sq. cm. was collected or a total of 0.256 mg. during the 8 hours. The sebum exuded at almost an even hourly rate during this interval. The gland thus has great potentialities to excrete sebum. If the sebum continued to exude at this rate over a period of 24 hours, the total accumulation would be very great. Table 1 shows that when the sebum is collected once every 12 hours or even at the end of a longer period the average of 0.123 mg./sq. cm. may be taken. This latter quantity represents approximately the amount which exudes in an interval of 4 hours. Thus apparently a limited accumulation is reached on the skin sur-

[2] Sebum and fat are used as synonyms in this paper.

face in a relatively short period. As pointed out previously, this limited accumulation could be regulated by the sebaceous layer resisting the output of the gland or it could be due to volatilization or resorption of the sebum when on the skin surface at a rate which equalizes the rate of the output of the gland.

While it was extremely unlikely that volatilization was responsible for the limited amount on the skin surface, it seemed worth investigating. Both sides of the forehead of an individual were cleaned with cotton containing ether and both were covered with shallow metal cups having a diameter of 3 cm. Twelve hours later, from one side of the forehead was collected 0.213 mg./sq. cm. while the other side was uncovered and left 4 more hours and then 0.223 mg. was taken. In another case 0.168 mg. was collected from one side which had been left uncovered and from the other side, which had been covered for 12 hours and then left uncovered for 7 hours, 0.276 mg. was collected. Covering the skin with perforated metal cups caused no increased accumulation.

These experiments indicated that there was not much lost by volatility or at least when uncovered, sebum did not volatilize down to the amount of the other side.

To test volatility further, both sides of the head were cleaned with cotton containing ether and covered for 12 hours. Collections were made from both sides and each collection was divided into equal parts. One part of the left side amounted to 0.119 mg./sq. cm. while one part of the right read 0.130 mg. The other parts were left in a temperature of 37.5°C for 24 hours and the left then read 0.126 mg. and the right 0.128 mg., (the slight variations between the parts of the same side are considered to be due to error). In another case the 12-hour accumulation from an uncovered side read 0.121 mg. while a half of the amount from the covered side for the same interval read 0.110 mg. The other half was left in a temperature of 37.5°C for 24 hours and then read 0.112 mg.

Two collections were taken from two other individuals. Each individuals' collections were pooled and divided into four parts. The fat content of the first part was immediately determined while the other parts were left in a temperature of 37.5°C for 48, 96 and 144 hours respectively. In one individual the readings were 0.066, 0.063, 0.060 and 0.062 mg. while in the other individual the readings were 0.083, 0.083, 0.081 and 0.093 mg.

These experiments presented evidence that there was little, if any, volatility of the sebum. Volatility was, therefore, not responsible for the limited amount that appeared on the skin surface. It was suggested in the introduction that the limited amount on the skin surface might be regulated by resorption. If resorption is the factor, then when a side is covered there should not be any increase in the accumulation. Resorption seems highly improbable since sebum apparently is not absorbed in sebaceous cysts where the epithelium of the walls of the gland duct is much thinner than the cornified surface epithelium.

Elimination of volatility and resorption as possible regulative mechanisms for the limited accumulation on the skin surface, leaves the resistance of the sebum as the most probable regulative factor.

3. *Means of Inducing Variation in the Weekly or Daily Amount of the Sebum on*

the Skin Surface. In our previous work (2) it was found that there was some variation in the amount of sebum which could be collected once weekly or daily. It seemed that if the cause of this variation could be found or if a variation could be induced when desired, that some information on the control of the general level of the sebaceous layer on the skin might be obtained. Fortunately, as shown previously by our experiments on volatilization, it was discovered that covering the skin with shallow cups would cause a variation.

The sebum was not collected for several days from the forehead near the hairline. The forehead was then cleaned with cotton containing ether and an area was covered with a shallow metal cup having a diameter of 3 cm. After 12 hours the sebum was collected from the covered area and from an adjoining uncovered area on the forehead and fat determinations were made. The first six cases in Table 1 present data obtained at three or four day intervals from the same individual and are characteristic of the determinations made on several other individuals. The average of 0.139 mg./sq. cm. was collected from the uncovered areas while the average collection from the covered areas was 0.273 mg./sq. cm., an increase of nearly 100%.

Twelve hours after a previous collection the forehead was cleaned and an area was covered for 12 hours. Then only 34% more fat (cases 7, 8, 9) was collected from the covered area. The time interval was too short for the glands to recover their full potentiality and the output could be no greater regardless of the covering.

The increased accumulation on the covered area could be due to an increase in temperature or moisture. Accordingly, it seemed desirable to learn the cause of the variation between the covered and uncovered areas.

There existed the possibility that the moisture of the perspiration under the shallow cup which covered the area was the factor which in some way caused an increase in the amount of sebum. A deeper cup containing a layer of calcium chloride which was separated from the skin by meshed wire was then used in covering areas. At three to four day intervals the skin was cleaned with ether prior to covering with the cup and the cup was then left in place for 12 hours at the end of which collections were made from the covered area and an uncovered area.

Cases 10, 11, 12, 13 show that 79% more sebum was collected from the areas covered with cups containing calcium chloride. When the cups were removed, the areas were dry. These experiments provided evidence that moisture was not the factor which caused a greater accumulation of sebum on the covered area.

Temperature was the remaining and the most logical factor as the cause of the increased sebum on the covered area.

Evidence that an increase in temperature was the factor was brought out by having an individual sit at three to four day intervals in a room having a temperature of 96°F for 80 minutes. The sebum was collected 10 hours later. Table 2 shows that ten collections, from the same individual used in the experiments in Table 1, averaged 0.209 mg./sq. cm. This average is much higher than the average of 0.123 mg. in Table 1 when the individual was in a temperature of

65–70°F. Further evidence that temperature influences the amount on the surface is presented by comparing the amounts taken during the winter months with those collections made during the summer months. Twenty readings at intervals during the winter months averaged 0.123 mg. while 20 readings from the same individual during the summer months averaged 0.156 mg. per sq. cm.

Table 1 (cases 1–9) shows that temperature caused an increased accumulation if there was little or no sebum present on the surface when the temperature or covering was applied. The next problem presented was would the temperature be as effective when considerable sebum existed on the skin at the time of covering.

To obtain information on this problem no sebum was removed for 3 to 4 days and then an area was covered for 12 hours. At the end of this period determinations were made for covered and uncovered areas. In seven such experiments (cases 14–20) an average of 0.118 mg./sq. cm. was collected from the uncovered area and an average of 0.215 was collected from the covered side, a 90% increase which compares favorably with the 100% increase when little or no sebum was present on the surface at the time of covering.

TABLE 2

Showing amount of fat collectable after exposure to high room temperature

RIGHT AREA	LEFT AREA
0.203	0.252
0.246	0.209
0.232	0.206
0.142	0.165
0.209	0.232
Average 0.206	0.213

The accumulation of sebum on the skin surface had been increased by covering the skin for 12 hours. It seemed quite possible that the accumulation might be further increased by covering for a longer period. The same area on the forehead near the hairline was covered with a cup for 12 hours each night for three successive nights. No collection was made during this interval and the individual avoided touching the area during the daytime. On the third day a determination was made. In 8 such experiments the collections averaged 0.240 mg./sq. cm. which is not much greater than the average accumulation of 0.215 mg./sq. cm. (Table 1) resulting from covering for a period of 12 hours. These experiments show that temperature was ineffective in increasing the level of the sebum on the skin beyond a certain limit.

An hour after the collections were made in the preceding experiments, another collection was taken. The average of eight such collections was 0.142 mg./sq. cm. and this yield represents the amount which had probably exuded from the duct in an hour. Collections from uncovered areas as shown in Table 1 average 0.123 mg./sq. cm. and an hour later, one is able to collect on the average of only 0.042 mg./sq. cm. Temperature, therefore, not only causes an increase in the

accumulation on the skin, but it also causes an accumulation or storage in the gland and when the quantity is removed from the surface, a rapid exudation takes place.

There existed the possibility that surface tension of the sebum in some way aided in regulating the exudation of the sebum. Ether appeared to be the best substance which would cause the spreading of the sebum without removing it and at the same time not interfere with the nephelometric method of determination of the fat. After an interval of several days areas on the forehead of the same individual used in experiments in Table 1 were exposed to fine ether spray several times over an interval of 48 hours. At the end of this interval the average of 4 collections was 0.145 mg./sq. cm. which was comparable to the 0.140 mg. from untreated areas. After making these collections, areas of the forehead were exposed to ether vapors for several minutes at 15 minute intervals over a period of an hour. At the end of this period collections were found to average 0.032 mg./sq. cm. which was less than the average amount of 0.042 mg./sq. cm. collected from untreated areas. Detergents and an emulsificant were also applied to areas of the forehead for 12 hours and these failed to appreciably increase the amount of sebum which could be collected. In the case of the emulsificant (triethanolamine) an average of 0.162 mg./sq. cm. was collected from 4 treated areas which was slightly higher than the 0.142 mg. collected from the untreated areas but not nearly so much as the average accumulation of 0.220 mg. which was induced by temperature.

DISCUSSION

Many facts have been brought out by these experiments. The fat is not confined entirely to conical masses at the orifices of the glands, but spreads along the sulci between the orifices. Since the fat is not confined to conical masses, surface tension in all probability does not provide the resistance to further exudation. Furthermore, exposure of the skin to ether and the application of detergents also failed to provide any evidence that the surface tension of the sebum aided in regulating the exudation.

By taking the collections hourly, it has been shown that the gland has great potentialities to excrete sebum. It has also been shown that volatilization and resorption do not regulate the level of the accumulation on the skin surface. The sebum on the skin in all probability retards further exudation for when the sebum is removed, more sebum exudes until a limited accumulation is reached in a short time.

Covering the skin resulted in an increased accumulation on the skin surface and this effect of covering was due to an increase in temperature. Temperature, however, was ineffective in increasing the accumulation beyond a certain limit.

A change in the viscosity of the sebum as it approaches and exudes from the gland orifices may provide the resistance to exudation. The cause of this change could be the temperature of the bare skin for it varies widely with the environmental temperature (Best and Taylor, (4)). Temperature increase could decrease the viscosity and thereby lower the resistance which would allow more

exudation or it could increase the blood supply to the gland which would increase the potentiality of the gland. Probably the accumulation on the surface is increased by both means.

It is impossible to alter the temperature of the skin surface without altering the vascularity of the skin. Therefore, no evidence has been secured to show that temperature has increased the accumulation via altering the viscosity. Determinations of the viscosity of sebum at various temperatures must be made to supply evidence that temperature alters the amount of sebum on the skin by affecting its viscosity. There has been evidence that temperature has increased the activity of the gland for there is a large accumulation in the gland after exposure to temperature. This large accumulation in the gland was shown by the greater exudation in the hour following a collection after covering or exposure to temperature for some time.

The effect of temperature possibly explains the large amount of sebum on the skin surface and the occurrence of frequent sebaceous cysts in the people living in tropical climates. Hormones, by altering vascularity, may have a similar effect as temperature. In the case of occasional cysts there are probably bacteria associated with the cyst which cause an irritation, increased blood flow and large glands.

It thus appears that when sebum is removed from the skin surface, the gland normally continues to excrete until its energy balances the resistance offered by the surface sebum. When the sebum on the skin is not removed, cell proliferation within the gland probably progresses at a low level. Increased vascularity or metabolism causes the gland to produce sebum which is added to the surface accumulation until a limited amount is reached and thereafter the sebum continues to be stored in the gland.

CONCLUSIONS

1. The sebum on the forehead is not confined to the orifices of the glands, but spreads along the sulci between the orifices.
2. The limited accumulation on the skin is not due to volatility or resorption of the sebum.
3. The sebum on the skin must provide resistance and be a factor in determining the amount on the skin.
4. An increase in temperature will increase the accumulation on the skin and the activity of the gland.

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